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WSDU*WATER.WET: THE COMPUTERIZED VERSION OF CHAPTER III - HYDROLOGY - OF THE WRENSS HANDBOOK

BY

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The program WSDU*WATER.WET was originally programmed by Mark Spearnak (USDA Forest Service). It has undergone additional testing and modification through the efforts of several USDA Forest Service personnel. Individuals warranting mention include, in alphabetical order, Cynthia Eichin, James Ingwersen, David Ryn, Steven Schmidt and James Weatherred.

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The efforts of the above are acknowledged and, moreover, appreciated. However, any errors of content or of omission from this document are solely those of the authors.

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1.0 INTRODUCTION

1.1 ARRANGEMENT OF REPORT

This WSDG report provides the user of the WSDU*WATER.WET program with a basic understanding of its origins, its conventions, its limitations, and the sensitivity of its variables. It also shows the user how to execute the program and presents available input data entry usage aids.

This report does not present the derivations, assumptions, and conceptualizations fundamental to understanding the hydrologic principles underlying this program. These are left to the reader to explore in the source document An Approach to Water Resources Evaluation of Non-Point Silvicultural Sources (A Procedural Handbook) (WRENSS), (USDA Forest Service 1980). The assumption of user competence (i.e., a trained hydrologist) made in WRENSS also applies to the user of WSDU*WATER.WET.

1.2 WRENSS

The source document for this program, "WRENSS", was developed by the USDA Forest Service under contract to Environmental Protection Agency. This document represents the state-of-the-art, at the time of its preparation, for field level determinations of selected non-point source pollution impacts from silviculture related activities. It includes chapters on controls, erosion, sediment, temperature, dissolved oxygen and organic matter, nutrients, introduced chemicals, and hydrology. Since most of the calculations associated with the various handbook chapters require an initial determination of the hydrologic response of vegetation removal, a need for an automated alternative to the worksheet approach of the Hydrology Chapter quickly surfaced. It was to satisfy this need that WSDU*WATER.WET program was developed. (For simplicity WSDU*WATER.WET will be referred to as WET hereafter.)

This program directly incorporates the nomographs depicted in WRENSS and utilizes the values derived therefrom for the same kind of calculations as would be accomplished using the worksheets. It does not calculate any of the basic functional relationships

described in WRENSS, i.e., ET (Evapotranspiration) modifier coefficients, seasonal ET, root depth modifier coefficients, etc. Thus this program, like WRENSS, incorporates the results of simulations produced by the Subalpine Water Balance Model (WATBAL) (Leaf and Brink 1973a, b), for snow-dominated regions and PROSPER (Goldstein et al. 1974) for rain-dominated regions.

Since the hydrology chapter of WRENSS is intended to predict changes in water yield relative to a calculated "baseline" or "undisturbed" value, it is recommended that a baseline simulation be made when running WET. All proposals and/or the existing condition may then be related to this background value to estimate the relative change in water yield and timing produced by management. Further, this relative change, when added to field measured values, can provide a more refined estimate of probable effects.

The reader should be aware that WRENSS does not identify any analysis as "baseline". The WRENSS nomenclature, also employed in WET, is "existing" and "proposed". It is intended that an "existing" analysis be of the "baseline" or "undisturbed" watershed and that "proposal A", "proposal B", etc. represent the current watershed condition and any alternative management scenarios of interest.

1.3 WRENSS ERATA

In the preparation and testing of this program, some errors in printing have been identified in the source book - WRENSS. The user must be aware of these to avoid misinterpretations of analysis results. Specifically, the following changes to WRENSS must be made.

1. Page III. 2. Under equation III.2, where P_f =, change line 4 from "... if $0 > P_f < 1$ ..." to "... if $0 < P_f < 1$ ...".

2. Page III. 34 (Figure III. 18). For soil depths greater than 3 feet, the dashed line applies to both the fall and summer seasons.

3. Page III. 34 (Figure III.20). Change the x-axis values from 1.5', 3', and 6' to 3', 6', and 12', respectively.

4. Page III. 51. Equation III.11, should read " $Q_i = b_0 + b_1Q_i + b_2CD + b_3AS + b_4RD + b_5$ Sine Day".

5. Page III.51. Under SINE DAY section, change "...December 21 as Day 1, January 1 as Day 11..." to "...November 21 as Day 0, December 1 as Day 10...".

6. Page III.51 (Table III.6). Change all the month column headings to read one month earlier (i.e., change Dec to Nov, Jan to Dec, and so on).

7. Page III. 82 (Figure III.30). Reverse "North Aspect" and "South Aspect" labels on curves (i.e., top curve should be labeled "South Aspect" and bottom curve should be labeled "North Aspect").

8. Page III.90 (Third Paragraph). Change "...Figures III.54 and III.55 should be..." to "...Figure III.53 should be...". Also, change "...Figures III.52 and III.53 are recommended..." to "...Figure III.50 is recommended...".

9. Pages III. 91-93 (Figures III.47-56). Change the words "energy aspects" beneath the figures to "elevations".

10. Page III. 107 (Table III.11). For 6th day interval No. 10, change 0.200 to 0.020 and .01425 to 0.1425 under the columns labeled "full forest" and "open (clearcut)" respectively.

11. Pages III.114 and III.115 (Figures III.67 and III.69). Reverse the energy aspect labels for these two figures so that Figure III.67 reads "high energy aspects" and Figure III.69 reads "low energy aspects".

12. Pages III.116 and III.117 (Figures III.71 and 73). Reverse the energy aspect labels for these two figures so that Figure III.71 reads "high energy aspect" and Figure III.73 reads "low energy aspect".

Other errors may remain undiscovered. Should users identify any such error an addendum to this report will be prepared as soon as possible.

2.0 THE PROGRAM

2.1 PROGRAM BACKGROUND

The WET program computes the yield and temporal distribution of water available for streamflow before and after silvicultural activities on fourth order and smaller forested watersheds. The programming structure of WET was designed to mimic Chapter III, Hydrology, of WRENSS. It is a batch program, which means there is no interaction between the program and the user during execution. The input data required by the program are contained on various combinations of formatted card images. During execution, the formatted card images are read by the program and processed. The reader should be aware at this point that, while WET is a batch program, a "front-end" data entry

interactive program called WSDU*WATER.WET-INLONG has been developed to assist the field hydrologist in the use of WET. (See Section 4.3.)

Program output includes: (1) an evapotranspiration summary and a water balance by sub-watershed area, (2) an estimate of total water available for streamflow by sub-watershed area, (3) an annual distribution by sub-watershed area of all water available for streamflow (in snow-dominated areas the mean annual discharge is distributed in a hydrograph through the snowmelt-runoff season only), (4) changes in streamflow for a specific date or flow level (for rain-dominated regions), and (5) all of the above summed for the entire watershed.

2.2 INPUT REQUIREMENTS

WET is inherently simple in its input data requirements. Specifically, the program requires as a minimum: (1) mean annual precipitation described on a seasonal basis, (2) watershed area, (3) an indication of the presence and windward length of openings in the canopy (if snow is to be redistributed), (4) latitude (for hydrologic region 2 only), (5) aspect of analysis area, (6) dominant vegetation type, (7) baseline cover density, leaf area index, or basal area (at full vegetative occupancy), (8) average tree height (if snow is to be redistributed), (9) average soil depth (for rain-dominated regions), (10) area and residual cover density, leaf area index, or basal area for any proposed or existing treatments (i.e., harvests), and (11) an indication of whether an area is a snow source, a deposition zone, or unaffected (if snow is to be redistributed).

The above data may be refined to describe smaller and smaller analysis areas. Furthermore, the user may elect to supply data on seasonal evapotranspiration, local hydrographs or flow duration curves, locally derived snow redistribution (retention) coefficients, and localized (area specific) precipitation. These choices are optional and serve to refine the output.

In order to execute WET, it is necessary to know the types of card images and the arrangement of information which are required by the program. Table 1 is a summary of

the types of card images which WET "expects" to encounter during execution. A brief explanation of the kind of information contained on each "card image type" is provided. Detailed information concerning the formats, input codes, and arrangement of data on these "card image types" is presented in Section 4.1 (Input Formats).

Table 1. Card Image Types.[1]

Card Image Type	Information
WRENSS ANALYSIS	Analysis identification Number of watersheds/analyses System of measurement
WATERSHED	Watershed/analyses identification Hydrologic region or province Dominant precipitation Watershed area and latitude Snow redistribution Number of prescriptions Existing or proposed conditions Output options
DISTRIBUTION	Flow duration curve or 6-day average annual hydrograph
PRECIPITATION	Watershed and/or prescription precipitation and evapotranspiration
PRESCRIPTION	Use of different precipitation values Prescription identification Prescription area Aspect Dominant vegetation (prescription) Baseline cover density/leaf area index Equivalent deciduous area Average tree height Average soil depth Number of silvicultural states Canopy opening
STATE	Silvicultural state identification Dominant vegetation (state) Cover density/leaf area index or basal area Area of silvicultural state Snow redistribution information Canopy opening Elevation classification
FLOW DURATION[2]	Number of points on a flow duration curve Number of specific flow changes Watershed leaf area index change
FDCURVE[2]	Known flow duration curve data
CHANGE[2]	Leaf area index change Stream flow change Date (sine day)

[1] Some of the card image types and the information listed are optional.

[2] These card image types are only used when applying the least squares technique as discussed on pages III.45-61 in WRENNS.

Different combinations of these input card images give the WET program a wide range of capabilities. For example, Figure 1 illustrates the simplest possible arrangement of card image types for a watershed analysis. For additional examples, see Appendix B.

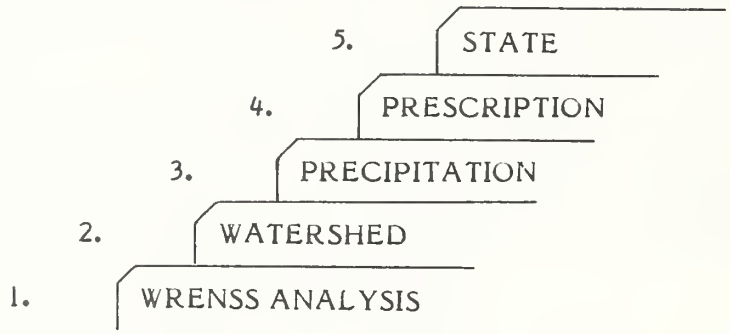


Figure 1. The simplest arrangement of card image types for a watershed analysis (one prescription, one state, and one ET/precipitation condition).

2.3 PROGRAM STRUCTURE

WET consists of a main program and several subroutines. Figure 2 illustrates the overall conceptual framework of the analysis process used by WET. The program calculates water balances for each "prescription" by "state" (see Section 2.4 for definitions), accumulates a total, then proceeds to the next prescription. When all prescriptions have been addressed, the sum of their individual totals represents the watershed total. It is at the prescription level that the variables of aspect, precipitation, ET, and soil depth can be described to represent conditions different from those of the watershed as a whole.

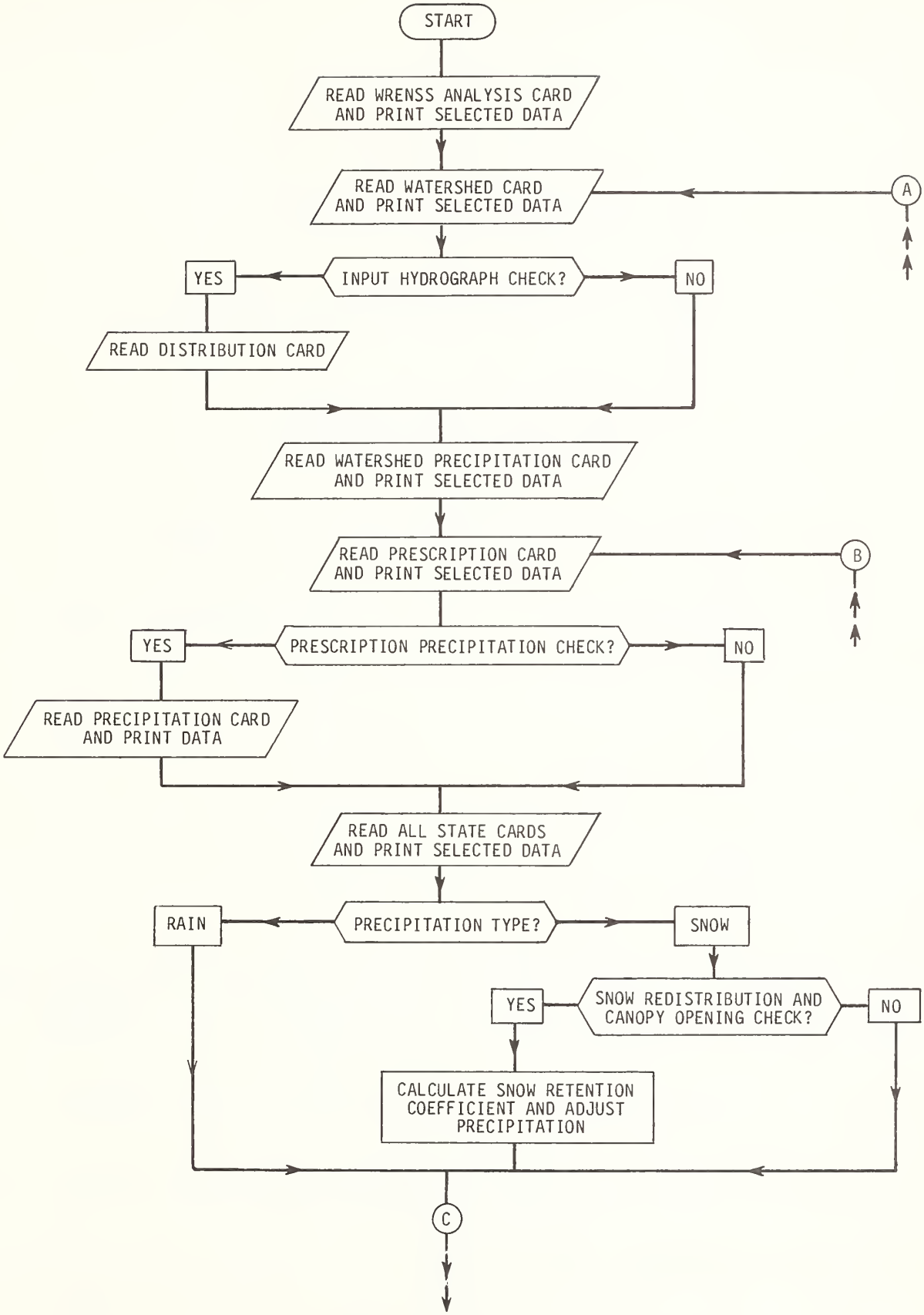


Figure 2.--Generalized WET Program Flowchart.

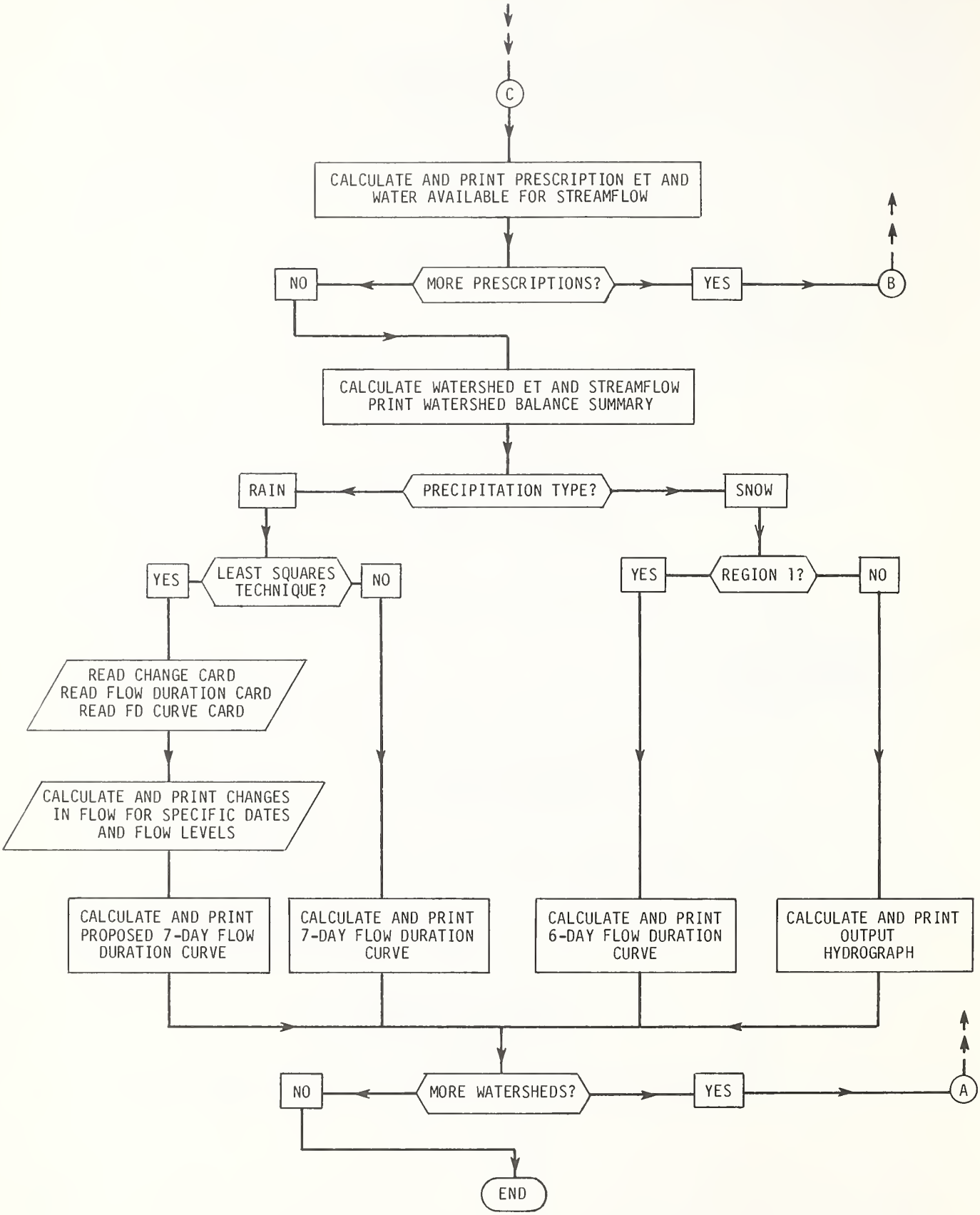


Figure 2.--Generalized WET Program Flowchart.

2.4 CONVENTIONS

The reader may have already noticed some nomenclature conventions which differ from common forestry usage. The terms "silvicultural prescription" and "silvicultural state" as used in WRENSS could lead to some confusion. Silvicultural prescription describes a contiguous area which is essentially homogeneous with respect to soil depth, type of vegetation, precipitation, aspect, and all other unique and significant site factors. A watershed is composed of one or more silvicultural prescriptions as the user chooses, so long as the sum of their areas equals that of the watershed. The term silvicultural state describes a condition of the vegetation within the area described by the silvicultural prescription. For example, the silvicultural state may be clearcut, thinned, fully forested, etc. There may be one or more different silvicultural states within a silvicultural prescription as long as the sum of their areas equals that of the prescription. There are program restrictions on the size of a watershed and the number of silvicultural states and prescriptions. Maximum watershed size is limited to 9999.9 acres or less and the user may designate up to 50 states within each prescription and up to 20 prescriptions within each watershed.

As noted earlier, differences in precipitation and ET from the overall watershed values can be described at the prescription level. Without such information (i.e., a prescription precipitation card), the program will default to the last set of ET/precipitation values whether the values were presented at the watershed or prescription level. Thus, if a user wants to use the watershed precipitation values on a prescription, say prescription number 4, after an intervening prescription, say prescription number 3, which uses its own precipitation card, a prescription precipitation card with the watershed values will be required for prescription number 4. All subsequent prescriptions will default to the precipitation card for prescription number 4 until another prescription precipitation card is encountered.

A further restriction is the requirement that, when calculating a mass balance for snow-dominated areas, only one "impacted" state (snow accumulation area) and one

"forested-impacted" state (snow source area) be designated within a prescription. Therefore, the user is faced with an initial choice when making analyses in which he/she desires to account for snow redistribution: (1) describe as many prescriptions as there are cut (impacted) areas, or (2) lump cut areas into larger imaginary units.

In making the snow redistribution analyses, the user must carefully review WRENSS (pages III.15-17 and III.76-78). In WET or WRENSS, the user can supply snow retention coefficients. In doing so, however, the user is responsible for completing an area-weighted mass balance. If this is not done, the user may "create precipitation" on the watershed. This was not the intent of WRENSS. WET, therefore, will attempt, on an area basis, to balance snow borrowed with snow deposited if the program is allowed to select a snow retention coefficient from the WRENSS ρ_o (rho) curve (page III.16) which is incorporated in WET.

In light of the cautions presented above, a judicious user of WET may expand its capabilities and avoid the one "impacted state" per prescription limitation. This is done by supplying the snow retention coefficients for the "impacted" and "forest-impacted" states. However, caution must be used in their selection to make certain that increases in area-weighted precipitation input to openings are balanced by equivalent area-weighted precipitation reductions in forested areas.

For extremely large openings, those whose width measured parallel to prevailing winds is 30 times the height of adjacent trees and more, WET will utilize a snow retention coefficient value of 0.5. Where greater precision is desired, the user may input a coefficient value generated by using the technique described in Appendix A of WRENSS.

Once water yield has been estimated, WET calculates hydrographs or flow-duration curves. These flow distributions are first produced at the prescription level and then accumulated to represent the distribution for the entire watershed.

The development of a hydrograph is accomplished by applying the incorporated WRENSS regional distribution for open and forested conditions to the area-weighted water yield produced by open and forested areas respectively. The distributions are then

summed by 6-day time periods. For partial cuts, an interpolated distribution is calculated between the open and forested distributions based upon percent reduction of cover density (see WRENSS, pages III.119 and III.122). This distribution, then, is applied to the area-weighted water yield for the partial cut area. The composite prescription hydrograph is then formed by the addition of water yield, by 6-day interval, from forested, open, and interpolated hydrographs.

When cover density is less than or equal to 5 percent of CD_{max}, an open hydrograph is used by WET rather than an interpolated set of values. Similarly, a forest hydrograph is applied when cover density is greater than or equal to 90 percent of CD_{max}.

Depending upon whether the user's hydrologic region or province is snow- or rain-dominated, either cover density or leaf area index is employed in the calculation of evapotranspiration modifier coefficients. The user has the option, however, of supplying basal area instead of cover density or leaf area index. It is recommended that the user, upon making a selection, continue to use the chosen option throughout the analysis for the watershed being simulated. This will serve as a precaution to avoid errors associated with possible misinterpretation of basal area/cover density or basal area/leaf area index relationships. Furthermore, given the option, the user is better off to use leaf area index or cover density where possible since these are the better descriptors of evapotranspiration.

The user of WET may be concerned with the fact that no opportunity exists to identify watershed areas that are of rock, tundra, or other non-timber characteristic. These areas should be identified by one of the vegetation types appropriate to the hydrologic region or province being simulated. This can be done since vegetation type, per se, does not affect water yield. It is only the change in cover density from baseline cover density (CD_{max}) that results in the application of ET modifier coefficients to baseline evapotranspiration. Any vegetation appropriate to the hydrologic region may be used to describe rock, tundra, etc., so long as the cover density employed is the same as the prescription baseline cover density value. NOTE: Use caution if using basal area for

a species different from the one used to develop the prescription baseline cover density (e.g., a basal area of 100 for spruce-fir has a different baseline cover density than a basal area of 100 for lodgepole pine).

The reader should be aware at this juncture that the nomographs depicted in WRENSS are not precisely reproduced in WET. This arises from the difficulties associated with the linearization of nonlinear curves for use in the program. However, the curves described in WET have been defined in such a way as to not differ from those in WRENSS by more than $\pm$ 5 percent of the WRENSS value. This precision was felt to be suitable to the purpose and nature of both the handbook and the program.

3.0 SENSITIVITY ANALYSES

By knowing how program output responds to changes in input variables, the user can identify those input variables demanding the most attention in selection and refinement. This can also lead to more effective data acquisition and use of time and effort. To illustrate how changes in various input variables result in changes in program output, the program computations will be fully analyzed. This should help the user develop a better understanding of the computational nature of this program and avoid the so-called "black-box approach" to program usage where the user enters data without understanding how that input data affects the resultant answer.

The program computations are very simple. The basic equation used in the program to compute water available for streamflow (i.e., water yield) is:

$$\text{Water Yield} = \text{Precipitation} - \text{Evapotranspiration}$$

Precipitation is a required user-supplied input for this program. In most cases, once precipitation is entered into the program , these values are not affected by any of the other input variables. The only exception occurs in some snow-dominated regions when snow redistribution is assumed. Under these conditions, snow retention coefficients can cause the user-supplied precipitation values to be modified. However, if the user defaults

to the program, it will use a mass balance, and as a result the same amount of annual water yield is computed with or without redistribution effects. This aspect of the program will be discussed in more detail later in this section.

In contrast, the evapotranspiration (ET) variable can be modified by several input variables. Most likely, a user will not enter baseline ET values directly, but will instead use the program's default values. In some hydrologic regions, baseline ET values are fixed. In other regions, baseline ET values are variable and the values computed by the program are based on other input data such as latitude, or aspect and precipitation. Once the baseline ET values are entered or computed, these values are adjusted by other input variables. The resultant adjusted ET values are then used by the program to compute water yield. Because adjusted ET values are sensitive to changes in a variety of input variables, most of the sensitivity analyses will focus on the response of ET to changes in other input variables.

The manner in which these input variables affect ET may be deduced from the following equations which describe the calculation of adjusted ET. For rain-dominated regions ET is calculated using (WRENSS, page III.33),

$$ET_A = ET_B \times C_{ET} \times RD \times \text{Silvicultural State Area}$$

where

ET_A = Site specific seasonal evapotranspiration loss for a specified activity

ET_B = Seasonal baseline evapotranspiration by latitude, if appropriate

C_{ET} = Evapotranspiration modifier coefficient taken by season for a specified leaf area index

RD = Rooting depth modifier coefficient

Silvicultural State Area = Area of silvicultural state as a decimal % of watershed area.

For snow-dominated regions ET is calculated using,

$$ET_C = ET_D \times C_{ETS} \times \text{Silvicultural State Area}$$

where

ET_C = Site specific seasonal evapotranspiration loss for a specified activity

ET_D = Seasonal baseline evapotranspiration taken by energy, aspect, and precipitation

C_{ETS} = Evapotranspiration modifier coefficient taken by season, aspect, and if appropriate, elevation

Silvicultural State Area = Area of silvicultural state as a decimal % of watershed area.

Some of the program input variables can also have a major influence on how the computed annual water yields are distributed over time. However, because the regionalized flow duration curves applied in all rain-dominated hydrologic regions are not affected by changes in any of the input variables, the effects of input changes on the distribution of water yield were analyzed in the snow-dominated region only.

Considering the magnitude of the task of evaluating the sensitivity of the program to changes in all the input variables for all the hydrologic regions and provinces, analyses were only done for two representative hydrologic regions: a rain-dominated region and a snow-dominated region. It is assumed that the other regions will show similar sensitivities.

For each of the regions selected, one set of input data was used. This was done primarily to have some common basis for comparing the results of individual sensitivity analyses for that region. The basic design of the sensitivity analyses was to change one input variable at a time through its normal range of values. This was done to isolate the output response resulting from changes in one specific input variable and thus avoid possible interactions caused by changing two or more input variables simultaneously. In addition, a few of the input variables for each region were selected as examples to show in detail how changes in specific input variables affect computed ET values, water yields, and flow distribution.

The input and output values presented in the following sensitivity analyses are applicable only to the given data sets and hydrologic regions described in this section. There is no reason to expect direct transfer to a different data set in the same region or to the same data set in a different region. However, this section attempts to help develop a better understanding of the program so reasonable judgments can be made when evaluating the program sensitivity to changes in input data appropriate to the user's region of interest.

3.1 RAIN-DOMINATED HYDROLOGIC REGION

The sensitivity analyses for a rain-dominated hydrologic region were done on a fictitious 100-acre watershed in hydrologic region 2 (Appalachian Mountains and Highlands). This watershed was described by a very simplified structure of only one prescription with one state. Except where a specific input variable was changed for a sensitivity analysis, the data values listed below were held constant.

Precipitation - 20.0 inches for each season

Latitude - 36 degrees

Aspect - East

Soil Depth - 4 feet

Vegetation - Mixed (50% deciduous, 50% conifer)

Baseline Leaf Area Index (LAI) - 7.0

RAIN-DOMINATED SENSITIVITY ANALYSIS I -- SOIL DEPTH CHANGE

Three different soil depths (2, 4, and 8 feet) were used. The soil depth values selected correspond to the range of soil depth shown in Figure III.19 (page III.34) of WRENSS. This figure is the nomograph used to calculate soil depth modifier coefficients in this region. The results of this analysis are listed in Table 2.

Table 2. Sensitivity Analysis Results - Soil Depth Change.

INPUT VARIABLE	SEASON	PRECIP-ITATION (inches)	BASELINE ET (inches)	ET MODIFIER COEFFICIENT	ROOT MODIFIER COEFFICIENT	ADJUSTED ET (inches)	WATER YIELD (inches)
Soil Depth 2 feet	Fall	20.0	7.3	1.00	.91	6.6	13.4
	Winter	20.0	3.4	1.00	1.00	3.4	16.6
	Spring	20.0	4.8	1.00	1.00	4.8	15.2
	Summer	20.0	14.7	1.00	.92	13.6	6.4
	ANNUAL	80.0				28.4	51.6
Soil Depth 4 feet	Fall	20.0	7.3	1.00	1.00	7.3	12.7
	Winter	20.0	3.4	1.00	1.00	3.4	16.6
	Spring	20.0	4.8	1.00	1.00	4.8	15.2
	Summer	20.0	14.7	1.00	1.00	14.7	5.3
	ANNUAL	80.0				30.2	49.8
Soil Depth 8 feet	Fall	20.0	7.3	1.00	1.12	8.1	11.9
	Winter	20.0	3.4	1.00	1.00	3.4	16.6
	Spring	20.0	4.8	1.00	1.00	4.8	15.2
	Summer	20.0	14.7	1.00	1.08	15.8	4.2
	ANNUAL	80.0				32.1	47.9

Results show that the soil depth input variable has a direct effect on the root depth modifier coefficient used for the fall and summer seasons. For example, at a soil depth of 2 feet, fall and summer root depth modifier coefficients were 0.91 and 0.92, respectively. In contrast, these same coefficients were 1.0 and 1.0 at the 4-foot depth, and 1.12 and 1.08 at the 8-foot depth. The net outcome of these soil depth input changes was annual adjusted ET values varying from 28.4 to 32.1 inches or an absolute change of 3.7 inches. This same absolute change of 3.7 inches was also found when comparing the water yield values (51.6 and 47.9 inches) computed for this range of soil depths.

RAIN-DOMINATED SENSITIVITY ANALYSIS II -- LEAF AREA INDEX CHANGE

Three different LAI values (7.0, 4.0, and 1.0) were used. These LAI values could represent a realistic case of evaluating the water yields from three different silvicultural treatments: baseline or fully forested (LAI = 7.0), thinning (LAI = 4.0), and clearcut (LAI = 1.0). In addition, the range of LAI values selected for this example corresponds closely to the range of values shown in Figure III.16 (page III.32) of WRENSS. This figure

is the nomograph used to determine ET modifier coefficients for this region. The results of this sensitivity analysis are summarized in Table 3.

Table 3. Sensitivity Analysis Results - Leaf Area Index Change.

INPUT VARIABLE	SEASON	PRECIP-ITATION (inches)	BASELINE ET (inches)	ET MODIFIER COEFFICIENT	ROOT MODIFIER COEFFICIENT	ADJUSTED ET (inches)	WATER YIELD (inches)
LAI = 7.0	Fall	20.0	7.3	1.00	1.00	7.3	12.7
	Winter	20.0	3.4	1.00	1.00	3.4	16.6
	Spring	20.0	4.8	1.00	1.00	4.8	15.2
	Summer	20.0	14.7	1.00	1.00	14.7	5.3
	ANNUAL	80.0				30.2	49.8
LAI = 4.0	Fall	20.0	7.3	0.93	1.00	6.8	13.2
	Winter	20.0	3.4	0.84	1.00	2.8	17.2
	Spring	20.0	4.8	0.84	1.00	4.0	16.0
	Summer	20.0	14.7	0.89	1.00	13.1	6.9
	ANNUAL	80.0				26.7	53.3
LAI = 1.0	Fall	20.0	7.3	0.52	1.00	3.8	16.2
	Winter	20.0	3.4	0.50	1.00	1.7	18.3
	Spring	20.0	4.8	0.45	1.00	2.2	17.8
	Summer	20.0	14.7	0.42	1.00	6.2	13.8
	ANNUAL	80.0				13.9	66.1

The results illustrate the direct effect that the LAI input variable has on the ET modifier coefficient for all seasons. For example, at a LAI value of 7.0, ET modifier coefficients were 1.00 for all seasons. Reducing LAI to 4.0 resulted in ET modifier coefficients of 0.93, 0.84, 0.84, and 0.89 for the fall, winter, spring, and summer seasons, respectively. Additional reduction of LAI to 1.0 yielded ET modifier coefficients of 0.52, 0.50, 0.45, and 0.42. The net outcome of these LAI changes was reflected in annual adjusted ET values varying from 30.2 (LAI = 7.0) to 13.9 inches (LAI = 1.0), or an absolute change of 16.3 inches. As with the first example, this absolute change is equally reflected in the differences in the water yield output (66.1 and 49.8 inches) for this given range of LAI values.

OTHER RAIN-DOMINATED SENSITIVITY ANALYSES

The program sensitivity to changes in other input variables (precipitation, latitude, vegetation, aspect) were also analyzed. These input variables were varied over a realistic range of values specific to each variable. For example, total precipitation was varied from 40 to 120 inches. The results from the analysis showed water yields to increase from 9.9 to 89.9 inches with no change in ET. This analysis clearly illustrated that changes in precipitation (80.0 inches) result in identical changes (80.0 inches) in water yield with no effect on ET. Latitude was changed from 34.0 to 41.0 degrees which resulted in a 6.4 inch change in both ET and water yield. The analysis demonstrated the effects that latitude has on baseline seasonal ET as shown in Figure III.11 (page III.28) of WRENSS. However, it is unlikely that this variable will normally be changed to any large degree by a user. Changing both the vegetation (deciduous, coniferous) and aspect (north, east, south, west) resulted in no changes in program output. These two analyses showed that these variables have no effect on the calculated ET or water yield.

SUMMARY OF THE RAIN-DOMINATED SENSITIVITY ANALYSES

The results of all analyses are summarized in Table 4 by listing the range of values and corresponding absolute changes in ET and water yield for each variable.

Table 4. Sensitivity Analysis Summary - Rain-Dominated Hydrologic Region.

INPUT VARIABLE	RANGE OF VALUES	CHANGE IN ET (inches)	CHANGE IN WATER YIELD (inches)
Annual Precipitation	40 to 120 inches	0.0	80.0
Latitude	34 to 41 degrees	6.4	6.4
Aspect	North, East, South, West	0.0	0.0
Leaf Area Index	1.0 to 7.0	16.3	16.3
Vegetation	Coniferous, Deciduous	0.0	0.0
Soil Depth	2.0 to 8.0 feet	3.7	3.7

In comparing the results of all the sensitivity analyses in Table 4, changes in precipitation resulted in the largest change in water yield. The analysis demonstrated that ET remained constant throughout the entire range of precipitation values tested and emphasizes that changes in precipitation were translated directly into water potentially available for streamflow. Reviewing the other results shows that changes in LAI had a larger effect on adjusted ET and thus on water yield, than any of the other variables. Based on these results, it probably would be more beneficial for the user to expend more time and effort in delineating and describing changes in precipitation and vegetative cover (LAI or basal area) of a watershed than the other variables listed in Table 4. However, two important points must be fully considered when reviewing the results listed in Table 4. First, the sensitivity of each input variable must be evaluated individually. Although one input variable may be less sensitive when compared with other variables, each variable can have a significant effect on the program output under certain conditions. For example, soil depth changes from 2 to 8 feet resulted in a net change in water yield of 3.7 inches. Under very high precipitation conditions, the effect of soil depth changes in terms of an overall percent change in water yield may be relatively minor. However, under very low precipitation conditions, percent changes in water yield could be very much larger based on the same soil depth changes. Second, the relative sensitivity of each input variable can change within a given range of values. In Rain-Dominated Sensitivity Analysis II, the change in LAI from 7.0 to 4.0 yielded a net change of 3.5 inches for water yield. In contrast, changing LAI from 4.0 to 1.0 resulted in a net change in water yield of 12.8 inches. These results reflect the curvilinear relationship between LAI and ET modifier coefficients (see Figure III.16, page III.32 of WRENSS). This aspect re-emphasizes that the user should carefully review the nomographs and equations in the WRENSS document to better understand the relative sensitivity of the input variables over specific ranges of input values.

3.2 SNOW-DOMINATED HYDROLOGIC REGION

The sensitivity analyses for a snow-dominated region were based on a fictitious 100-acre watershed in hydrologic region 4 (Rocky Mountain/Inland Intermountain). This watershed was partitioned into one prescription with one state for Snow-Dominated Sensitivity Analyses I and II . The watershed design for Snow-Dominated Sensitivity Analysis III also had one prescription but was divided into two equal-sized states with one of the states representing the "open" condition and the other state the "forested-impacted" condition. Except where a specific input variable was changed for a sensitivity analysis, the data values listed below were held constant.

Precipitation - 16.0 inches for each season

Aspect - South

Soil Depth - 4 feet

Vegetation - Lodgepole Pine

Baseline Cover Density (CD_{max}) - 0.50

Cover Density - 0.50

Snow Retention Coefficient - 1.0

SNOW-DOMINATED SENSITIVITY ANALYSIS I -- COVER DENSITY CHANGE

Three different cover density (CD) values (0.50, 0.25, 0.00) were tested. These values were chosen to demonstrate the effects on water yields for three different silvicultural states or treatments: fully forested (CD = 0.50), thinned (CD = 0.25), and clearcut (CD = 0.00). These values represent the complete range of values used to determine ET modifier coefficients in this Region (see Figure III.46, page III.91 of WRENSS). The results of this analysis are listed in Table 5.

Table 5. Sensitivity Analysis Results - Cover Density Change.

INPUT VARIABLE	SEASON	PRECIP-ITATION (inches)	BASELINE ET (inches)	ET MODIFIER COEFFICIENT	ADJUSTED ET (inches)	WATER YIELD (inches)	PEAK FLOW (cfs)	TIME OF PEAK FLOW (6 day interval)
CD - 0.50 (100% CD_{max})	Winter	16.0	2.3	1.00	2.3	13.7		
	Spring	16.0	8.0	1.00	8.0	8.0		
	Sum/Fall	16.0	9.3	1.00	9.3	6.7		
	Annual	48.0			19.6	28.4	3.14	12
CD - 0.25 (50% CD_{max})	Winter	16.0	2.3	1.00	2.3	13.7		
	Spring	16.0	8.0	1.03	8.2	7.8		
	Sum/Fall	16.0	9.3	1.00	9.3	6.7		
	Annual	48.0			19.8	28.2	2.52	11
CD - 0.00 (0% CD_{max})	Winter	16.0	2.3	.60	1.4	14.6		
	Spring	16.0	8.0	1.05	8.4	7.6		
	Sum/Fall	16.0	9.3	.60	5.6	10.4		
	Annual	48.0			15.4	32.6	3.78	9

This analysis illustrates the effect that CD has on the ET modifier coefficients. For example, at a CD value of 0.5 (100% CD_{max}), ET modifier coefficients were 1.00 for all seasons. Decreasing CD to 0.25 (50% CD_{max}) resulted in ET modifier coefficients of 1.00, 1.03, and 1.00 for the winter, spring, and summer/fall season respectively. Further reduction of CD to 0.00 (0% CD_{max}) yielded seasonal ET modifier coefficients of 0.60, 1.05, and 0.60. The net outcome of changing CD from 1.00 to 0.00 resulted in a change in adjusted ET and water yield of 4.2 inches. However, when compared to the full-forest condition (CD-0.5) reducing the cover density by 50 percent (CD-0.25) actually yielded a slight increase (0.2 inches) in adjusted ET with an identical decrease in water yield. This analysis shows that for this region changes in CD do not have a large effect on the water yield output until CD is decreased to a value less than 50 percent of CD_{max}.

Changing the CD input variable also had a major influence on how water yields were distributed. At a CD value of 0.5, water yields were partitioned into the forested-flow hydrograph. For the clearcut condition (CD-0.0) water yield was distributed into the open-flow hydrograph. Finally, at a CD value of 0.25, water yield was partitioned into an interpolated-flow hydrograph distribution. Because of these shifts in distribution, peak

flow increased from 3.14 to 3.78 cfs and the time of peak flow was earlier by three time intervals (18 days) by decreasing CD from 1.0 to 0.0. In addition, although the actual amount of water yield changed very little, reducing CD from 0.5 to 0.25 resulted in a decrease in peak flow from 3.14 to 2.52 cfs and time of peak flow to advance by one time interval.

SNOW-DOMINATED SENSITIVITY ANALYSIS II -- PRECIPITATION CHANGE

In snow-dominated regions, seasonal precipitation may have a major effect on seasonal baseline ET values. The range of seasonal precipitation values was selected for this example to illustrate these effects and emphasize the curvilinear relationship between these two variables. Three different conditions were analyzed based on total precipitation values of 48, 24, and 12 inches divided equally between the three seasons. The results of this sensitivity analysis are summarized in Table 6.

Table 6. Sensitivity Analysis Results - Precipitation Change.

INPUT VARIABLE	SEASON	PRECIP-ITATION (inches)	BASELINE ET (inches)	ET MODIFIER COEFFICIENT	ADJUSTED ET (inches)	WATER YIELD (inches)	PEAK FLOW (cfs)	TIME OF PEAK FLOW (6 day interval)
Precip-itation 16"/Season	Winter	16.0	2.3	1.00	2.3	13.7		
	Spring	16.0	8.0	1.00	8.0	8.0		
	Sum/Fall	16.0	9.3	1.00	9.3	6.7		
	ANNUAL	48.0			19.6	28.4	3.14	12
Precip-itation 8"/Season	Winter	8.0	2.3	1.00	2.3	5.7		
	Spring	8.0	6.9	1.00	6.9	1.1		
	Sum/Fall	8.0	9.0	1.00	9.0	-1.0*		
	ANNUAL	24.0			18.2	5.8	0.64	12
Precip-itation 4"/Season	Winter	4.0	2.3	1.00	2.3	1.7		
	Spring	4.0	4.1	1.00	4.1	-0.1*		
	Sum/Fall	4.0	7.8	1.00	7.8	-3.8*		
	ANNUAL	12.0			14.2	-2.2*	--	--

* Negative values indicate storage depletion

The results of this analysis show that when total precipitation was 48 inches (16 inches per season), baseline ET was 2.3, 8.0, and 9.3 inches for the winter, spring, and

summer/fall seasons respectively. At a total precipitation of 24 inches (8 inches per season), baseline ET decreased to 6.9 and 9.0 inches for the spring and summer/fall seasons while remaining the same for the winter season. Additional reduction of total precipitation to 12 inches (4 inches per season) yielded a much larger decrease in the spring and summer/fall ET values (4.1 and 7.8 inches) while the winter value remained unchanged.

The net outcome of this sensitivity analysis in annual adjusted ET and water yield is more complex than previous analyses, primarily because both baseline ET and precipitation are changing simultaneously for each simulation run. To better describe these results, seasonal ET/precipitation curves (see Figures III.24-26, pages III.79-80 of WRENSS) must be reviewed over the range of seasonal precipitation values selected for this analysis. At 16 inches per season, all seasonal ET values are located on the flat part of the ET/precipitation curves and thus, are at their maximum values. Actually, for any precipitation value greater than 11 inches, all seasonal baseline ET values are maximized and do not change with changes in precipitation.

Changing seasonal precipitation from 16 to 8 inches per season resulted in a small decrease of 1.4 inches in adjusted ET with a large reduction of 22.6 inches in water yield. Over this range of precipitation, the spring and summer/fall ET/precipitation curves are sloping slightly downward, demonstrating a small reduction in ET. However, most of the reduction in water yield resulted from the reduction in precipitation.

At 4 inches of precipitation per season, there was a much larger change in adjusted ET because of the increased slope of the ET/precipitation curve. However, even over this range of precipitation (8 to 4 inches) the change in precipitation is greater than that of ET, which means that most of the decrease in water yield is due to the reduction in precipitation.

Precipitation changes also have a major effect on the distribution of water yield. For example, there was no change in the time of peak flows, but peak flow changed from none to 3.14 cfs when seasonal precipitation was increased from 4 to 16 inches.

The important point to be made with this analysis is that for this region, at lower seasonal precipitation values (e.g., less than 11 inches), baseline ET was dependent on precipitation, and that this relationship is curvilinear. At higher seasonal precipitation values, baseline ET was independent of precipitation.

SNOW-DOMINATED SENSITIVITY ANALYSIS III -- SNOW RETENTION COEFFICIENT CHANGE

As previously mentioned, the watershed design used for this analysis consisted of one prescription divided into two 50-acre states with each state having the same cover density to eliminate the effect of the CD variable. One of the states represented the "open" condition and the other the "forest-impacted" condition. Three different sets of snow retention coefficients (1.30-0.70, 1.15-0.85, and 1.00-1.00) were used. The first value of each pair of coefficients was applied to the "open" state, and the second to the "forest-impacted". These snow retention coefficients closely approximate the coefficient values that would be applied if the "open" state of this watershed consisted of clearcut openings of 5h, 10h, and 15h, respectively. The results of this sensitivity analysis are shown in Table 7.

Table 7. Sensitivity Analysis Results - Snow Retention Coefficient Change.

SEASON-STATE	PRECIP-ITATION (inches)	SNOW RETENTION COEF.	ADJ. PRECIP. (inches)	BASE ET (inches)	ET MOD. COEF.	ADJ. ET (inches)	AREA* WEIGH FACTOR	WATER YIELD (inches)	PEAK FLOW (cfs)	TIME PEAK (6-day)
Winter-Forest	16.0	0.70	11.2	2.3	1.00	2.3	0.5	4.4		
Open	16.0	1.30	20.8	2.3	0.60	1.4	0.5	9.7		
Spring-Forest	16.0	0.70	11.2	8.0	1.00	8.0	0.5	1.6		
Open	16.0	1.30	20.8	8.0	1.05	8.4	0.5	6.2		
Sum/ - Forest	16.0	1.00	16.0	9.3	1.00	9.3	0.5	3.4		
Fall Open	16.0	1.00	16.0	9.3	0.60	5.6	0.5	5.2		
ANNUAL								30.5	2.99	9
Winter-Forest	16.0	0.85	13.6	2.3	1.00	2.3	0.5	5.6		
Open	16.0	1.15	18.4	2.3	0.60	1.4	0.5	8.5		
Spring-Forest	16.0	0.85	13.6	8.0	1.00	8.0	0.5	2.8		
Open	16.0	1.15	18.4	8.0	1.05	8.4	0.5	5.0		
Sum/ - Forest	16.0	1.00	16.0	9.3	1.00	9.3	0.5	3.4		
Fall Open	16.0	1.00	16.0	9.3	0.60	5.6	0.5	5.2		
ANNUAL								30.5	2.85	9
Winter-Forest	16.0	1.00	16.0	2.3	1.00	2.3	0.5	6.8		
Open	16.0	1.00	16.0	2.3	0.60	1.4	0.5	7.3		
Spring-Forest	16.0	1.00	16.0	8.0	1.00	8.0	0.5	4.0		
Open	16.0	1.00	16.0	8.0	1.05	8.4	0.5	3.8		
Sum/ - Forest	16.0	1.00	16.0	9.3	1.00	9.3	0.5	3.4		
Fall Open	16.0	1.00	16.0	9.3	0.60	5.6	0.5	5.2		
ANNUAL								30.5	2.71	9

*Area Weigh Factor = State Area Divided By Total Watershed Area

Results of this analysis illustrate how precipitation is redistributed (adjusted precipitation) in the "open" and "forest-impacted" states based on changes in snow retention coefficients. However, redistribution of precipitation did not affect the resultant annual adjusted ET and water yields since all three simulation runs had the same results (annual water yield = 30.5 inches). These results re-emphasize that this program uses a mass balance approach in the redistribution of precipitation.

Although there were no changes in the annual water yield, there were minor changes in how that water yield was distributed. For example, at higher snow retention coefficients more of the precipitation was redistributed into the "open" state, which

resulted in a larger proportion of the water yield distributed as open flow. Over the range of snow retention coefficients used in this analysis, the proportion of annual water yield in the "open" state changed from 21.1 inches at a snow retention coefficient of 1.3, to 16.3 inches at a snow retention coefficient of 1.0. This change in the amount of water yield distributed as open flow resulted in a total peak flow decrease from 2.99 to 2.71 cfs. However, there was no shift in the 6-day interval containing the peak flow for all three simulation runs.

OTHER SNOW-DOMINATED SENSITIVITY ANALYSES

Another sensitivity analysis was conducted which basically combined the objectives of Snow-Dominated Sensitivity Analysis II (change in precipitation) and Snow-Dominated Sensitivity Analysis III (change in snow retention coefficient). The major difference in this analysis from the other two was that only two sets of snow retention coefficients (1.25-0.75 and 1.0-1.0) were used. Since the result of the analysis using higher precipitation values (16 inches per season) revealed no change in ET, even though precipitation was redistributed, this analysis was designed to determine if the effect was the same at lower precipitation values.

The results of this analysis, which are summarized in Table 8, were basically the same as that of Snow-Dominated Sensitivity Analysis III; changes in snow retention coefficients did not affect resultant annual water yields, but did cause some minor changes in peak flow values. There were some very small differences in annual water yield when comparing the results from the two different sets of snow retention coefficients. However, for lower precipitation conditions, 8 and 4 inches per season, slightly higher water yields were obtained when no snow redistribution occurred (snow retention coefficients of 1.0-1.0). These minor differences in annual water yield are most likely a function of the curvilinear relationship between precipitation and baseline ET. This analysis illustrates that this program is also insensitive to changes in snow retention coefficients at lower precipitation conditions.

Table 8. Sensitivity Analysis Results - Changing Both Precipitation and Snow Retention Coefficients.

SEASONAL PRECIPITATION	SNOW RETENTION COEFFICIENTS	WATER YIELD (inches)	PEAK FLOW (cfs)	TIME OF PEAK FLOW (6-day interval)
16	1.00 - 1.00	30.5	2.71	9
16	0.75 - 1.25	30.5	2.94	9
8	1.00 - 1.00	7.9	0.74	9
8	0.75 - 1.25	7.8	0.83	9
4	1.00 - 1.00	-0.3*	-	-
4	0.75 - 1.25	-0.4*	-	-

* Negative Values indicate storage depletion.

The sensitivity of the program to changes in aspect was also analyzed. ET, water yield, and flow distribution effects were evaluated for eight different aspects - north, northeast, east, southeast, south, southwest, west, and northwest. The results of this analysis are summarized in Table 9.

Table 9. Sensitivity Analysis Results - Aspect Change.

INPUT VARIABLE	ANNUAL ADJUSTED ET (inches)	ANNUAL WATER YIELD (inches)	PEAK FLOW (cfs)	TIME OF PEAK FLOW (6-DAY interval)
NORTH	16.7	31.3	2.53	16
NORTHEAST	17.4	30.6	2.47	16
EAST	18.1	29.9	2.94	15
SOUTHEAST	18.8	29.2	3.22	12
SOUTH	19.6	28.4	3.14	12
SOUTHWEST	18.8	29.2	3.22	12
WEST	18.1	29.9	2.94	15
NORTHWEST	17.4	30.6	2.47	16

These results show that south aspect had the highest ET value (19.6 inches) with the lowest water yield (28.4 inches). In contrast, north aspect had the lowest ET value (16.7 inches) with the highest water yield (31.3 inches). Flow distribution varied, from the southeast and southwest aspects having the highest peak flows (3.22 cfs) at the earliest time interval (12), to northeast and northwest aspects having the lowest peak flow (2.47 cfs) at the latest time interval (16). In addition, identical results were computed for each of the following pairs of aspects: northeast-northwest, southeast-southwest, and east-west.

SUMMARY OF SNOW-DOMINATED SENSITIVITY ANALYSES

All of the sensitivity analyses for the snow-dominated region are summarized in Table 10 by listing the range of values and corresponding absolute changes in ET, water yield, peak flow, and time of peak flow for each variable. As previously discussed with the summary of results (Table 4) for the rain-dominated region, the program sensitivity to each input variable must be evaluated individually and throughout a given range of values.

TABLE 10. Sensitivity Analysis Summary - Snow-Dominated Hydrologic Region.

INPUT VARIABLE	RANGE OF VALUES	CHANGE IN ET (inches)	CHANGE IN WATER YIELD (inches)	CHANGE IN PEAK FLOW (cfs)	CHANGE IN TIME OF PEAK FLOW (6-day interval)
ANNUAL PRECIPITATION	12 to 48 inches	5.4	30.6	3.14	0
COVER DENSITY	0.0 to 0.5 (0%-100% CD_{max})	4.4	4.4	1.26	3
SNOW RETENTION COEFFICIENT	1.0 to 1.3	0.0	0.0	0.28	0
ASPECT	N,NE,E,SE, S,SW,W,NW	2.9	2.9	0.75	4

In comparing the results of the sensitivity analyses for the snow-dominated region, water yield and peak flow were most sensitive to changes in precipitation. In most cases, changing precipitation resulted in the same change in water yield. The only exception

occurs at lower precipitation conditions where both precipitation and baseline ET are changing at the same time. However, even under these conditions, changes in precipitation usually accounted for most of the change in the simulated water yield. As with the rain-dominated region, silvicultural changes (i.e., cover density changes) resulted in the next largest change in water yield and peak flow.

An important result of the sensitivity analyses for the snow-dominated region was that changing snow retention coefficients caused no changes in water yield with very minor effects on flow distribution. The reason the WET program is insensitive to snow redistribution effects is that very generalized regional ET/precipitation relationships and ET modifier coefficients are used which most likely mask the influence snow redistribution may exert on changes in water yield and timing. In order to expand the capacity of the WET program and make it more sensitive to the potential effects of snow redistribution, user-supplied ET values will be needed which approximate the snow redistribution effects on ET relationships at more site-specific locations.

4.0 RUNNING THE PROGRAM

4.1 INPUT FORMATS

The format of each card image type is described in Table 11 in the general order of placement in the input "data deck". Special note should be made of the precipitation card image type. This card must follow the watershed card. It may, however, be additionally placed after prescription cards if the user wants to supply different precipitation and/or ET data for one or more prescriptions. The format is the same regardless of placement.

Table 11. Input Formats and Codes for the WET Card Image Types.
(Note: Starred Items are Required)

Card Image Type	Columns	Format	Description
* WRENSS ANALYSIS	1-14	2A6,A2	* WRENSSANALYSIS
	16-45	5A6	* WRENSS analysis identification
	48-50	I3	* Number of watersheds or analyses Minimum: 1 Maximum: 99
	52	I1	* System of measurement 1 = Metric Blank or 2 = English
	54	I1	WRENSS ANALYSIS card output option 1 = Do not print WRENSS ANALYSIS card Blank = Print WRENSS ANALYSIS card
* WATERSHED	1-9	3A3	* WATERSHED
	10-39	5A6	* Watershed or analysis identification
	41-42	I2	* Hydrologic region or province code number 1 = New England/Lake States Region 2 = Appalachian Mountains and Highlands Region 3 = Eastern Coastal Plain and Piedmont Region 4 = Rocky Mountain/Inland Intermountain Region 5 = Northwest Province 6 = Continental/Maritime Province 7 = Central Sierra Province
	44	I1	* Dominant precipitation code 1 = Rain 2 = Snow
	45-50	F6.1	* Watershed area (acres or hectares)
	52	I1	* Snow redistribution code 1 = Likely 2 = Not likely
	53-54	I2	* Number of prescriptions in watershed Minimum: 1 Maximum: 20
	56	I1	* Canopy opening code 1 = Canopy opening in watershed 2 = No canopy opening in watershed
	58	I1	* Condition code (up to 9 conditions) 1 = Existing 2 = Proposed-A 3 = Proposed-B etc.
	59	I1	Streamflow distribution input code 0 or Blank = No input 1 = Normalized baseline 6-day average watershed hydrograph follows 2 = Baseline regional 7-day average flow duration curve follows
	60-61	I2	Number of intervals for input hydrograph or for input flow duration curve, i.e., number of distribution cards (if Col. 59 coded 1 or 2) (NOTE: Required - 61 if using a hydrograph or 12 if using a flow duration curve.)

Table 11. Input Formats and Codes for the WET Card Image Types.
(Note: Starred Items are Required)

Card Image Type	Columns	Format	Description
	62	I1	Prescription streamflow output options 1 = Prescription hydrographs and watershed hydrograph printed (snow-dominated) or prescription flow duration curve and watershed flow duration curve printed (Hydrologic Region 1). (NOTE: Prescription flow duration curves for rain-dominated regions are never calculated.) 2 = No hydrographs or flow duration curves printed Blank = Only watershed hydrographs or flow duration curves printed
	63	I1	Output option 1 = Do not print PRESCRIPTION card 2 = Do not print WATERSHED card 3 = Do not print either STATE or PRESCRIPTION cards 4 = Print neither PRECIPITATION nor WATERSHED cards 5 = Print neither PRECIPITATION nor PRESCRIPTION nor STATE cards 6 = Print neither WATERSHED nor PRESCRIPTION nor STATE cards 7 = Print none of the above cards Blank = All cards printed
	64-65	I2	Evapotranspiration/water balance/file output option 1 = Evapotranspiration summary not printed 2 = Prescription water balance summary not printed 3 = Watershed water balance summary not printed 4 = Both ET and prescription water balance summaries not printed 5 = Both prescription and watershed water balance summaries not printed 6 = Both ET summary and watershed water balance summaries not printed 7 = Print none of the above Blank = Print all of the above (NOTE: Diagnostic messages always printed.)
	66	I1	* FD Curve Code (applies only to least squares technique - see WRENSS, pages III.45-61). 1 = User will provide either a flow curve or will provide flow and/or date(s) 2 = No curve, flow, or dates supplied (NOTE: Required for rain-dominated regions only; if snow-dominated region, may enter [0 or blank].)
	67	I1	* Specific flow change code (applies only to least squares technique - see WRENSS, pages III.45-61). 0 or Blank = No input needed 1 = Flow duration curve only 2 = Specific flow changes only 3 = Both (NOTE: Required if FD curve code [1] is selected in Col. 66.)
	69-72	F4.1	Latitude (degrees) (NOTE: Required for Hydrologic Region 2 only.)

Table 11. Input Formats and Codes for the WET Card Image Types.
(Note: Starred Items are Required)

Card Image Type	Columns	Format	Description
DISTRIBUTION	1-12	2A6	DISTRIBUTION (used if user supplies hydrograph or flow duration curve)
	14-18	F5.1	For a hydrograph - enter the number of the 6-day interval (i.e., 1, 2, 3, ...61) For a flow duration curve - enter the percent of time the flow is equaled or exceeded starting with 0% and incrementing by 10%, last value = 0.0 (i.e., 0.0, 10.0, 20.0, ... 100.0, 0.0)
	23-31	F9.4	For a hydrograph - enter the corresponding normalized 6-day discharge (i.e., decimal % of total annual discharge). For a flow duration curve - enter the corresponding average flow in centimeters or inches (last value = total annual flow in centimeters or inches). (NOTE: A hydrograph will have 61 lines, a flow duration curve will have 12 lines.)
* PRECIPITATION	1-13	2A6,A1	* PRECIPITATION (NOTE: See Appendix A for reference to seasons. Enter precipitation and evapotranspiration values in centimeters or inches.)
	15-19	F5.1	* Seasonal precipitation, season 1
	20-24	F5.1	* Seasonal precipitation, season 2
	25-29	F5.1	* Seasonal precipitation, season 3
	30-34	F5.1	* Seasonal precipitation, season 4 (NOTE: Enter zero in those hydrologic regions having only 3 seasons.)
	35-41	F7.2	Seasonal baseline evapotranspiration, season 1 (optional)
	42-48	F7.2	Seasonal baseline evapotranspiration, season 2 (optional)
	49-55	F7.2	Seasonal baseline evapotranspiration, season 3 (optional)
	56-62	F7.2	Seasonal baseline evapotranspiration, season 4 (optional)
* PRESCRIPTION	1-12	2A6	* PRESCRIPTION
	13	I1	PRECIPITATION card code 1 = PRECIPITATION card follows next in deck Blank = Default to most current PRECIPITATION card
	14-28	3A5	* Identification of prescription
	29-34	F6.1	* Prescription area (acres or hectares)

Table 11. Input Formats and Codes for the WET Card Image Types.
(Note: Starred Items are Required)

Card Image Type	Columns	Format	Description
	35	I1	* Prescription aspect code 1 = North 5 = South 2 = Northeast 6 = Southwest 3 = East 7 = West 4 = Southeast 8 = Northwest
	36	I1	* Dominant vegetation code 1 = Lodgepole Pine 6 = Douglas Fir 2 = Spruce-Fir 7 = Coniferous 3 = Ponderosa Pine 8 = Deciduous 4 = Western Larch 9 = Mixed 5 = Hemlock-Spruce
	37-41	F5.2	* Baseline cover density (decimal %), or baseline leaf area index (dimensionless)
	42-46	F5.1	* Basal area (ft^2/ac or m^2/ha) (NOTE: Required if baseline cover density or baseline leaf area index unknown.)
	47-52	F6.1	Equivalent deciduous area (acres or hectares) (NOTE: Required if mixed vegetation code [9] is selected in Col. 36.)
	53-57	F5.1	* Average tree height (feet or meters)
	58-72	3A5	Soil identification
	73-76	F4.1	* Average soil depth (feet or meters)
	77-78	I2	* Number of silvicultural states in prescription Minimum: 1 Maximum: 50
	79	I1	* Canopy opening code 1 = Canopy opening in prescription 2 = No canopy opening in prescription
* STATE	1-5	A5	* STATE
	7-21	3A5	* Identification of state
	22-23	I2	* Dominant vegetation code 1 = Lodgepole Pine 6 = Douglas Fir 2 = Spruce-Fir 7 = Coniferous 3 = Ponderosa Pine 8 = Deciduous 4 = Western Larch 9 = Mixed 5 = Hemlock-Spruce
	24-28	F5.2	* Cover density (decimal %) or leaf area index (NOTE: Enter -1 if unknown.)
	30-34	F5.1	Basal area (ft^2/ac or m^2/ha) (NOTE: Required if cover density or leaf area index unknown.)
	35-40	F6.1	* Area of silvicultural state (acres or hectares)
	41-46	F6.1	* Equivalent deciduous area (acres or hectares) (NOTE: Required if mixed vegetation code [9] is selected in Col. 22-23.)

Table 11. Input Formats and Codes for the WET Card Image Types.
(Note: Starred Items are Required)

Card Image Type	Columns	Format	Description
	48	I1	* Compartment code 1 = Impacted 2 = Forested impacted 3 = Unimpacted (NOTE: Only one STATE card may be coded as 1 per prescription. Only one STATE card may be coded as 2 per prescription. While this variable must be coded in all cases, it has no computational significance for rain-dominated regions. For regions where snow is redistributed and for prescriptions with a canopy opening, compartment codes have precise meaning as discussed on page 35 of this Report.)
	50	I1	* Canopy opening code 1 = Canopy opening in state 2 = No canopy opening in state
	51-56	F6.1	Windward length of open area (feet or meters) (NOTE: Required if canopy opening code [1] is selected in Col. 50.)
	58-61	F4.2	* Snow retention coefficient (dimensionless) For snow-dominated regions only (Enter -1.0 if unknown)
	63	I1	Elevation classification (NOTE: Enter for regions 6 and 7, see WRENSS, pages III.91-93.) 1 = Low 2 = Intermediate 3 = High
FLOW DURATION[1]	1-13	2A6,A1	FLOW DURATION
	15-16	I2	Number of points on the known flow duration curve; not used if changes only desired
	18-19	I2	Number of specific flow changes desired
	21-25	F5.1	Change in leaf area index for the watershed
FDCURVE[1]	1-7	A6,A1	FDCURVE
	9-14	F6.2	Percent of time flow is equaled or exceeded
	16-21	F6.2	Corresponding flow (cm. or inches)
CHANGE[1]	1-6	A6	CHANGE
	8-13	F6.2	Reduction in leaf area index
	15-20	F6.2	Corresponding preactivity flow (cm. or inches)
	22-25	F4.0	Day number (sine date)

[1] These card image types are used only when applying the least squares technique - see WRENSS, pages III.45-61 for detailed description.

While most of the items on the previous list are self explanatory, a few warrant elaboration.

WATERSHED Card Image:

Snow Redistribution Code - (Col. 52)	Select only if snow redistribution effects are to be analyzed.
Canopy Opening Code - (Col. 56)	An opening must be present for snow to be redistributed. Such an opening must be significant enough in size and location to perturb the normal snow carrying wind patterns.
Condition Code - (Col. 58)	The existing condition equates to the baseline or undisturbed watershed. The watershed as it exists today would be proposed A.
Streamflow Distribution Input Code - (Col. 59)	The kind of time series a user will supply. "No input" should be selected if the user wants to utilize the WRENSS curves.

PRESCRIPTION Card Image:

Dominant Vegetation Code - (Col. 36)	Code 9 - "mixed" refers to mixed deciduous and coniferous vegetation.

STATE Card Image:

Dominant Vegetation Code - (Col. 22-23)	Code 9 - "mixed" refers to mixed deciduous and coniferous vegetation.
Compartment Code: (Col. 48)	
Impacted -	Canopy opening in which snow will be deposited.
Forested Impacted -	Forested area from which snow is depleted for deposition in canopy opening area.
Unimpacted -	Forested area from which no snow is depleted.
Elevation Classifications - (Col. 63)	Refer to WRENSS, pages III. 91-93. (Note: Figures III.47-56 all have a labeling error. The term "energy-aspect" should read "elevation".) This identifier is used for WRENSS Regions 6 and 7 only.

In addition, if the user of the WET program wishes to supply snow retention coefficients to avoid the limitations upon the number of impacted states, the set of card types and input codes listed in Table 12 should be employed.

Table 12. WET Card Types and Input Codes Needed to Avoid Limitations Upon Number of Impacted States When Entering User Supplied Snow Retention Coefficients.

Card Image Type	Columns	Value	Description
WATERSHED	52	1	Snow redistribution likely
	56	1	Canopy opening in watershed
PRESCRIPTIONS	79	1	Canopy opening in prescription
STATE	48	3	Unimpacted
	50	2	No canopy opening in state
	58-61	X.XX	Snow retention coefficient value

4.2 PROGRAM EXECUTION

An example of the control statements which may be used to execute WET and direct output to a print file using the Univac 1100/84 computer at the Fort Collins Computer Center (FCCC) is as follows:

```
@ASG,UP printfile.
@BRKPT PRINT$/printfile
@XQT WSDU*WATER.WET
@ADD filename.
@BRKPT PRINT$
@FREE printfile.
@SYM printfile, ,siteid
```

(NOTE: Items in lower case print are user selected identifiers.)

where "filename" is the name of the file containing the arranged WET input card images specified above. Alternatively the user can issue the following command on a demand terminal,

```
@START runfile.
```

where file "runfile" contains a complete job such as,

```
@RUN,priority runid,acct#,projectid,time,pages
@SYM PRINT$, ,siteid
@XQT WSDU*WATER.WET
WRENSS ANALYSIS...
WATERSHED...
PRECIPITATION...        or @ADD filename
PRESCRIPTION...
STATE...
@FIN
```

4.3 USAGE AIDS

WSDU*WATER.WET-INLONG PROGRAM

To aid in the construction of the data deck previously described, a "front-end" data entry program called WSDU*WATER.WET-INLONG (WET-INLONG hereafter) has been developed. WET-INLONG is an interactive program which prompts the user for appropriate information by "asking" a series of questions. This "front-end" program places coded information on the various card images and arranges them for proper execution of WET. To initiate the WET-INLONG program, issue the following command at a demand terminal.

```
@XQT WSDU*WATER.WET-INLONG
```

When executing WET-INLONG, the user has the option of having WET executed automatically with the WET input coming from the data deck created during the "prompting for information" phase. If this option is selected, the following command sequence is generated and automatically invoked after the WET-INLONG program terminates.

```
@ASG,UP FILE.
@BRKPT PRINT$/FILE
@DATA,L 10.
@END
@XQT WSDU*WATER.WET
@ADD 10.
@BRKPT PRINT$
@FREE FILE.
@SYM FILE., ,SITEID
```

SITEID refers to the printer site where the output from WET is to be sent. The user will be prompted for this information when the automatic execution of the WET program option is selected. The data file (FILE) has a unique identification name based on the date and time the WET-INLONG program is actually executed by the user. In addition, the user will see the message, "READY" displayed twice on his or her terminal. The "READY" message occurs, once in response to the @ASG,UP statement and once in response to the @FREE statement. This command sequence is similar in form and effect to the first command sequence presented in the previous section.

When the execution of WET-INLONG ceases, the WET data deck which was created remains in temporary file "10". If the user wishes to retain this data deck, then the following command should be issued,

```
@ASG,UP filename.
@COPY 10.,filename.
```

where "filename" is the name of the file which will contain the WET input card images.

WSDU*WATER.WET-INSHORT

After becoming familiar with the interactive "front-end" WSDU*WATER. WET-INLONG program, the user may wish to speed up the question-response process by using a modified version of this interactive program. This modified version is called WSDU*WATER.WET-INSHORT. It prompts the user for the desired information without explanatory notes or listings of possible answers. The user must, therefore, already know the correct responses. Outside of this brevity, the two programs WSDU*WATER.WET-INLONG and WSDU*WATER.WET-INSHORT are identical. To initiate the WET-INSHORT program, issue the following command at a demand terminal.

```
@XQT WSDU*WATER.WET-INSHORT
```

These usage aids should facilitate the use of the WET program. The user can create and retain WET data decks and then employ the editing ability of the Univac computer to alter and/or create new data decks. With the ability to create additional data decks by

issuing a few editing commands, the user can evaluate numerous land management scenarios very quickly as might be necessary in a land management planning situation.

4.4 EXAMPLES

To assist first time users, examples of the execution of WET and one of its associated usage aid programs (WET-INLONG) have been developed and are contained in WSDG Report Series, WSDG-TN-00007, "Examples of the Input and Output for the WSDU*WATER.WET and WSDU*WATER. WET-INLONG Programs", (Daddow and Williams, 1984). This report describes the desired analysis, the input data used, and the resultant output for three examples of WET and one example of WET-INLONG.

In addition to this report, a set of example WET input files, listed in Appendix C, has been established at FCCC. There is at least one example for each WRENSS hydrologic region or province. Those regions/provinces which employ both the rain and snow-dominated analysis techniques have examples of each technique.

It is suggested that the user examine the example(s) for her/his region or province to gain familiarity with WET and its options. A listing of the input and resultant WET output may be obtained by submitting the following commands.

```
@PRT,S WSDU*SAM.WETDATAnumber
@XQT WSDU*WATER.WET
@ADD WSDU*SAM.WETDATAnumber
```

The "number" at the end of the first and third commands refers to a user-supplied number selected from the list of WET input data files from Appendix C. For example, if a user wanted to review an example of the WET input and output for a rain-dominated watershed analysis from hydrologic province 5, the following commands should be entered.

```
@PRT,S WSDU*SAM.WETDATA5A
@XQT WSDU*WATER.WET
@ADD WSDU*SAM.WETDATA5A
```

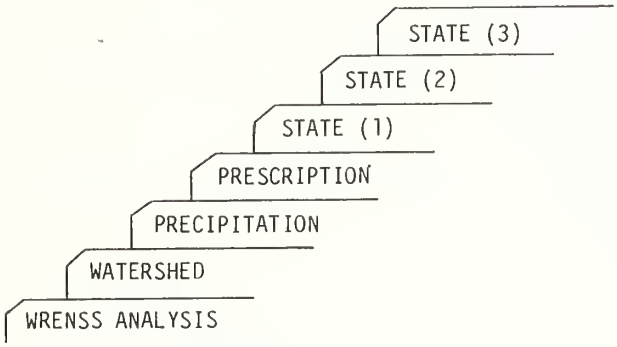
APPENDIX A

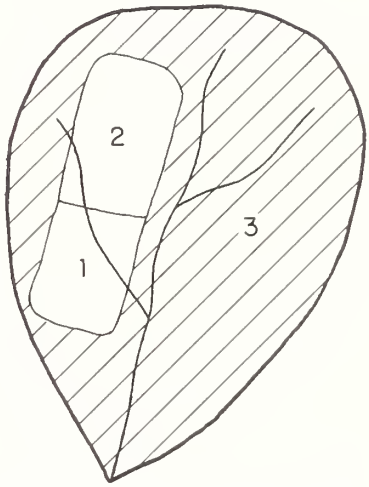
WRENSS Precipitation Seasons By Hydrologic Region/Province

Hydrologic Region or Province	Season Number	Season Name	Months
1	1	Fall, Early Winter	Oct, Nov, Dec, Jan
(Snow-dominated)	2	Late Winter, Early Spring	Feb, Mar, Apr
	3	Growing Season	May, Jun, Jul, Aug, Sept
2,3,5,6,7	1	Fall	Sept, Oct, Nov
(Rain-dominated)	2	Winter	Dec, Jan, Feb
	3	Spring	Mar, Apr, May
	4	Summer	Jun, Jul, Aug
4,6	1	Winter	Oct, Nov, Dec, Jan, Feb
(Snow-dominated)	2	Spring	Mar, Apr, May, Jun
	3	Summer and Fall	Jul, Aug, Sept
5,7	1	Early Winter	Oct, Nov, Dec
(Snow-dominated)	2	Late Winter	Jan, Feb, Mar
	3	Spring	Apr, May, Jun
	4	Summer and Fall	Jul, Aug, Sept

APPENDIX B

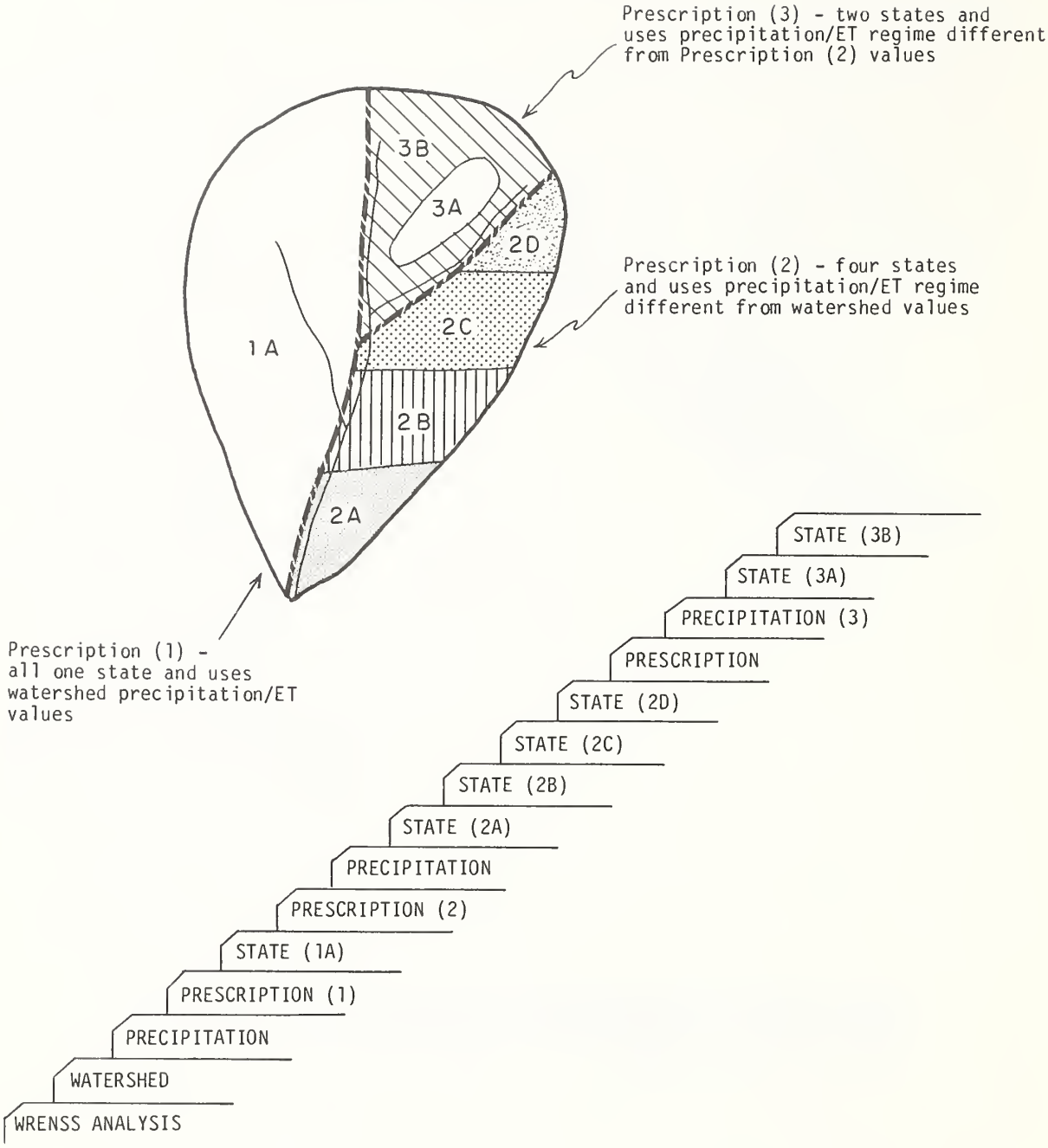
Examples of WET Program Card Deck Arrangement





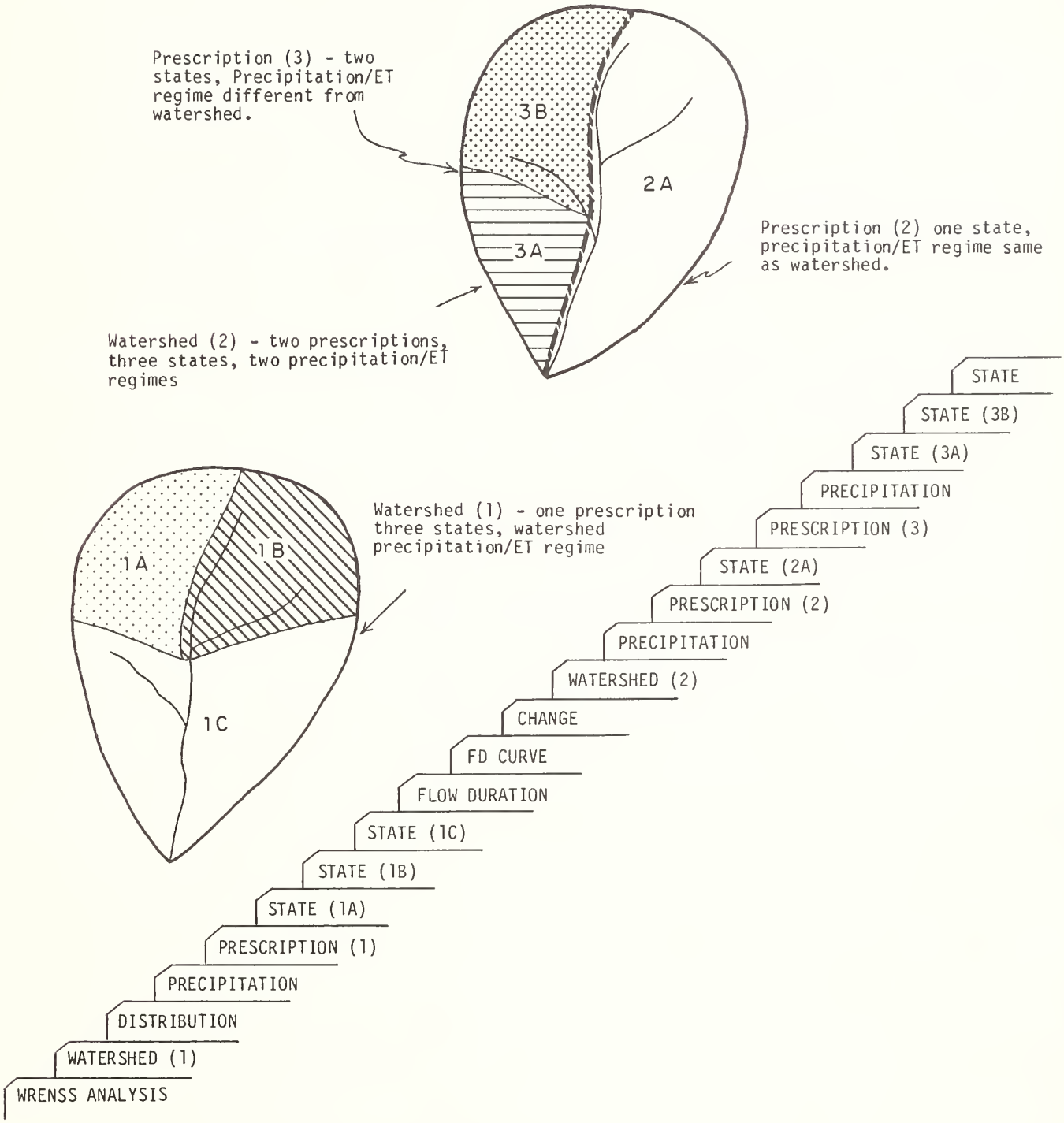
One prescription - three states, precipitation/ET same as watershed values.

A simple snow redistribution example - one prescription, an impacted (open) state (1), an impacted forest (snow depleted) state (2), and an unimpacted forest state (3).



A little more complex data set - three prescriptions, seven states, three precipitation/ET regimes.

APPENDIX B
(continued)



A more complex data set (two watersheds with user supplied flow duration curves and specific changes - applicable to rain dominated).

APPENDIX C

List of WET Input Data File Examples

WSDU*SAM.WETDATA1A for Hydrologic Region 1

WSDU*SAM.WETDATA1B for Flow Duration Curve Input (Region 1)

WSDU*SAM.WETDATA2A for Hydrologic Region 2

WSDU*SAM.WETDATA2B for Flow Duration Curve and Specific Changes Input (Region 2)

WSDU*SAM.WETDATA3 for Hydrologic Region 3

WSDU*SAM.WETDATA4A for Hydrologic Region 4

WSDU*SAM.WETDATA4B for Hydrograph Input (Region 4)

WSDU*SAM.WETDATA5A for Hydrologic Province 5 (Rain)

WSDU*SAM.WETDATA5B for Flow Duration Input (Region 5 - Rain)

WSDU*SAM.WETDATA5C for Hydrologic Province 5 (Snow)

WSDU*SAM.WETDATA6A for Hydrologic Province 6 (Rain)

WSDU*SAM.WETDATA6B for Hydrologic Province 6 (Snow)

WSDU*SAM.WETDATA7A for Hydrologic Province 7 (Rain)

WSDU*SAM.WETDATA7B for Hydrologic Province 7 (Snow)

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